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REQUIREMENTS DOCUMENT FOR EVALUATION OF ENVIRONMENTALLY PREFERABLE AIRCRAFT ELECTRICAL CONNECTORS

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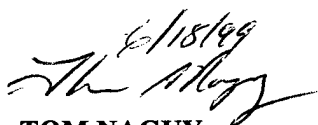
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This document describes the minimum requirements and desirable characteristics for an environmentally preferable electrical connector for use on U. S. Air Force aircraft. This report also describes a proposed test procedure that can be used to evaluate candidate connectors.

Environmentally-preferable connectors should be made from materials less hazardous than those used in existing connectors, but that still possess adequate grounding and corrosion resistance. The hazardous materials of concern are the EPA-17 chemicals, including cadmium, chromium, and nickel, currently used in the manufacture of MIL-C-38999J Series I and II, finish B, and Series III and IV, Classes J and W, connectors.

This document is divided into the following sections:

- ☐ Section 1, Background, provides background information that defines the nature of the problem.
- ☐ Section 2, Requirements, establishes the general requirements for an environmentally preferable connector.
- ☐ Section 3, Test Layout, describes the order of the tests conducted on each connector.
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- ☐ Section 5, Protocols, describes the procedures that will be used to evaluate candidate connectors.

This document can be used as a basis for a formal test procedure.

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List of Acronyms

AFRL	Air Force Research Laboratory
CAS	Chemical Abstract Service
DC	Direct current
DLA	Defense Logistics Agency
EMI	Electromagnetic interference
EMP	Electromagnetic pulse
EPA	Environmental Protection Agency
EPA-17	Environmental Protection Agency's List of 17 Targeted Industrial Toxic Chemicals
IVD	Ion vapor deposited
kA	Kiloamperes
kg	Kilograms
RFI	Radio frequency interference
SAE	Society of Automotive Engineers

1 Background

Electrical connectors are used throughout aircraft to provide connections between electrical cables and electronics boxes and to allow easy replacement of cables and components. Connectors must work flawlessly in all weather conditions and every possible thermal environment found on the aircraft. Some connectors are exposed to deicing fluids and cleaning solvents used on the aircraft. The connectors located in wheel wells and on the underside of the aircraft have the greatest exposure to potentially corrosive chemicals. Not all connectors can perform in every environment, but cadmium-plated connectors are the preferred connectors for corrosive environments at temperatures up to 175°C.

The cables within the aircraft are jacketed to provide electromagnetic interference (EMI) and electromagnetic pulse (EMP) protection for the wires contained in the cable. In order for this protection to function adequately, the shielding must be well grounded. Grounding is accomplished by electrically connecting the shielding for the cable to the connector and the connector to the components and/or the aircraft frame. To help ensure that the shielding is uniform, it is important that the connections to components or airframe be uniformly conductive. Connectors may be attached to other connectors or to the bulkhead, so a good electrical bond is necessary both from shell-to-shell (i.e., between the connector halves) and from shell-to-plate (i.e., between the socket half of the connector and the airframe or box).

The integrity of the electrical bond is threatened by corrosion, which is the natural degradation of materials in the environment. Whenever a metal surface is exposed to the environment, there is the possibility that the surface will corrode. Corrosion will occur if dissimilar metals are connected as well as when metals are placed in a galvanic cell (an electrolyte with electrical current present). When corrosion occurs, resistance usually increases slowly, and that increase in resistance could lead to a failure of the electrical bond and of related electrical circuits.

To help prevent corrosion, the surfaces of electrical connectors are plated or treated with nickel, cadmium and chromium. These materials are known or suspected human carcinogens and are on the Environmental Protection Agency's (EPA) list of 17 industrial toxic chemicals that are targeted for reduction or elimination (see Table 1). The Air Force has committed to eliminate or reduce the use of EPA-17 chemicals.

If one assumes there are 1,000 cadmium-coated connectors per aircraft, there are an estimated 6.4 million connectors with cadmium in the combined fleet of the Air Force, Air Force Reserves and Air National Guard. With an estimated 0.8 grams of cadmium per connector, there are approximately five metric tons of cadmium in the combined fleet attributable to electrical connectors. There are also roughly 0.1 grams of nickel per cadmium-plated connector (used as an underplate) or a little less than one metric ton of nickel attributable to connectors

fleet-wide (this does not count the nickel contained in nickel-plated connectors). The amount of chromium (from protective chromate conversion coatings) is not known, but assumed to be on the order of fractions of milligrams per connector.

Table 1. EPA-17 Industrial Toxic Chemicals

Name	CAS Number
Benzene	71-43-2
Cadmium and compounds	-
Carbon tetrachloride	56-23-5
Chloroform	67-66-3
Chromium and compounds	-
Cyanide compounds	-
Dichloromethane (methylene chloride)	75-09-2
Lead and compounds	-
Mercury and compounds	-
Methyl ethyl ketone (MEK)	78-93-3
Methyl isobutyl ketone	141-79-7
Nickel and compounds	-
Tetrachloroethylene	127-18-4
Toluene	108-88-3
1,1,1-Trichloroethane	71-55-6
Trichloroethylene	79-01-6
Xylenes	-

2 Requirements

The ideal connector shell will not contain any of the EPA-17 Industrial Toxic Chemicals nor use any in its manufacture. Most importantly, the environmentally preferable electrical connector must meet minimum (mandatory) performance requirements before it can be considered as a candidate for replacing cadmium-plated connectors. Once the field is narrowed to those that meet the minimum requirements, the candidates will be compared using additional characteristics such as EMI leakage attenuation and lubricity.

In general, the connectors should meet the following goals. The mandatory requirements and characteristics for comparison are described later in this section.

At a minimum, an acceptable shell will not contain cadmium and will not require more nickel than is used currently in cadmium-plated connector shells. Chromium should be limited to the use of a protective film containing chromium (i.e., conversion coating), although there is a preference for either no protective films or chromate-free films.

The highest priority performance requirements are: (a) to maintain a low electrical resistance over time between the shell and the aircraft airframe (shell-to-plate) and between two connector halves (shell-to-shell); and (b) to maintain corrosion resistance.

The connector must meet prescribed connector intermateability dimensions, accessory interface dimensions, etc. as provided in MIL-C-38999J. Connector manufacturers may modify dimensions not critical to connector function or the aircraft interface, but the preferred connector will not require dimension changes.

The connector manufacturer or airframe manufacturer may not use gaskets or conductive sealants in the assembly of the connectors.

2.1 Mandatory Requirements

A connector must meet all of the following mandatory requirements before it can be considered a candidate for replacing cadmium-plated electrical connectors.

2.1.1 Material Composition

No cadmium or chromium can be in the connector shells, and no more nickel than is currently contained in similar cadmium-plated connector shells. Chromium is limited to a chromate conversion coating, although there is a preference for no chemical films or chromate-free films.

2.1.2 Electrical Specifications

- ☐ Maximum resistance: 2.5 millivolt drop with a 1 amp current using the "Bond Resistance Test" procedure described in the protocol section of this document.

- ☐ Corrosion resistance: After 250 hours of salt spray as specified in the "Salt Spray Test - 250 hours" protocol, the voltage drop can be no more than 5 millivolts.

2.1.3 Mechanical Specifications

Minor dimension variations from those given in MIL-C-38999J will be accepted; however, mounting hole locations and overall length can not be changed.

2.1.4 Logistical Factors

- ☐ Availability of Technology: Candidate materials or manufacturing technologies must not be proprietary to a single supplier but must be licensable to a U.S. source or in the public domain.
- ☐ Cost: The estimated production price of any candidate connectors must be no more than double the price of similar cadmium-plated connectors.
- ☐ Weight: The weight of any candidate connector can be up to 20% greater than that of similar cadmium-plated connector shells.

2.2 Characteristics for Comparison

The following characteristics will be used to compare the candidate connectors to one another and to the control group of cadmium-plated connectors.

2.2.1 Material Composition

The use of all EPA-17 industrial toxic chemicals should be avoided. The supplier must note if any of these chemicals are contained in or used during the manufacture of the connector.

2.2.2 Electrical Specifications

- ☐ Bond resistance: Shell-to-plate bond resistance will be compared using the "Bond Resistance Test" protocol.
- ☐ EMI leakage attenuation: After undergoing the "EMI Leakage Attenuation Test," candidates will be compared.
- ☐ Lightning strike: Connectors will be tested according to the "Lightning Strike Test" protocol and evaluated for physical damage.

2.2.3 Mechanical Specifications

- ☐ Lubricity: Samples will be tested using the "Lubricity Test" protocol and compared.
- ☐ Mating and Unmating Forces: Samples will be tested in accordance with "Mating and Unmating Forces Test" protocol.
- ☐ Physical dimensions: Any changes from the physical dimensions given in MIL-C-38999J will be noted.

2.2.4 Environmental Specifications

- ☐ Corrosion resistance: Resistance will be measured after the "Salt Spray Test - Extended."
- ☐ Fluid resistance: Connectors will be evaluated on DC resistance increases, discoloration and corrosion after the "Fluid Resistance Test."
- ☐ Shock: Connectors will be compared after undergoing the "Shock" test.
- ☐ Thermal cycling: Connectors will be evaluated after the "Thermal Cycling Test" to see if materials have separated or delaminated.
- ☐ Thermal treatment: Connectors will be evaluated after the "Thermal Treatment Test" to see if some of the plating or composite layers have broken down.
- ☐ Vibration: Connectors will be evaluated after being tested by the "Sine Vibration Test" and "Random Vibration Test" protocols.

2.2.5 Logistical Factors

- ☐ Cost: Suppliers will estimate the relative cost factor between the current cadmium-plated connectors and the proposed alternative.
- ☐ Manufacturing processes: The supplier must supply a detailed description of the materials and processes used to manufacture candidate connectors. Information marked proprietary will be protected.
- ☐ Weight: Connectors will be weighed. The weight of the candidate will be divided by the weight of the current cadmium-plated connector and reported as a weight factor.

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3 Test Layout

The tests are divided into two phases:

- ☐ Phase I - mandatory connector requirements; and,
- ☐ Phase II - characteristics for comparison.

Results from each phase will be compared to those from a control group of cadmium-plated connectors. Connector shells must meet the mandatory requirements that will be tested during Phase I. Shells that meet those requirements will continue to Phase II of the tests.

Table 2 shows the tests that will be conducted on each connector.

Table 2. Test Matrix

Socket Number	Plug Number	Test
1	-	Salt spray – 250 hours
1	1	Lightning strike
2	-	Long term resistance
3	2	Shell-to-shell resistance Bond resistance Thermal treatment Bond resistance Shell-to-shell resistance Salt spray – 250 hours Mating and unmating forces Bond resistance
4†	3†	EMI leakage attenuation Lubricity Shock Bond resistance
5	-	Thermal cycling
6	-	Salt spray – Extended
7*	-	Bond resistance Salt spray – 250 hours Bond resistance Salt spray – 100 hours Bond resistance Repeat 100 hours salt spray and bond resistance until failure or 1500 hours
8	-	Sine vibration Random vibration Random vibration
9	4	Fluid immersion
* Non-chromate chemical conversion coat on plate.		
† Connector needs to be fully functional.		

The tests focus on the resistance between the connector receptacle and the airframe or electronics box because that area has been problematic. Because these tests are focusing on the shell-to-plate connection (bond resistance), nine sockets (i.e., the connector half that is fastened to the airframe or box) and four

plugs (i.e., the connector half that plugs into the other half) are required. The first two columns in Table 2 give the socket and plug connector numbers that will be used for the tests.

4 Rationale for Requirements and Characteristics

The purpose of these requirements is to identify more environmentally desirable connector materials and configurations. The mandatory requirements, which will be measured in Phase I tests, are less stringent than current requirements for cadmium-plated connectors. Connectors that meet these mandatory requirements will then be evaluated in Phase II. It is anticipated that a connector configuration can be found that will provide adequate or superior characteristics and not use any EPA-17 chemicals in its manufacture.

4.1 Material Composition

It is preferable to specify that no EPA-17 industrial toxic chemicals can be used in connector shells or during the manufacturing process. However, nickel is used so extensively as an underplate in the plating industry that the elimination of nickel is unlikely in the foreseeable future. Therefore, the presence of nickel in the candidate connector shells is acceptable. The amount, however, will be limited to a typical underplate (i.e., not more than currently applied to cadmium-plated connectors).

Likewise, protective chemical films (conversion coatings) contain chromium. Non-chromate conversion coats are available, but are not in widespread use since they are new to the market and have not been adequately tested for all applications. Therefore, the use of chromate conversion coatings is acceptable, although connectors that do not require a protective chemical film with chromium will be rated higher.

4.2 Electrical Specifications

4.2.1 Bond Resistance

MIL-C-38999J does not specify a shell-to-plate bond resistance value; however, the generally accepted minimum resistance is a 2.5 millivolt drop or 2.5 milliohm resistance. MIL-STD-464, "Electromagnetic Environmental Effects Requirements for Systems" provides a rationale for each requirement set forth in the standard. Regarding the DC resistance, MIL-STD-464 states:

"2.5 milliohms has long been recognized as an indication of a good bond across a metallic surface, particularly aluminum. There is no technical evidence that this number must be strictly met to avoid problems. A realistic value would be on the order of 10 milliohms from the shield to the electronics enclosure for a cadmium-plated aluminum assembly, with 2.5 milliohms maximum for any particular joint."

The selection of a specific shell-to-plate bond resistance level may be different between systems and subsystems. The selection of a universal bond resistance level is not possible, but should be as low as possible to protect sensitive and critical equipment. A 2.5 milliohm shell-to-plate bond resistance is assumed to

be adequate for most applications, although lower levels may be necessary on some systems.

4.2.2 EMI Leakage Attenuation

The likelihood of electromagnetic interference increases as the power requirements of electronic equipment continue to decrease. Many engineers consider this the critical parameter in the design of an electronic system. The EMI leakage test is difficult and time consuming to run, so it was not included in Phase I. Because it is a critical parameter, it is included in Phase II tests.

4.2.3 Lightning Strike

Lightning is a major hazard to electrical systems on aircraft. Electrical systems can be affected by both direct and indirect lightning. Traditionally it was thought that as long as the DC resistance was below 2.5 milliohms, lightning effects would be minimal. However, recent studies conducted by the Navy have revealed that physical damage caused by lightning can also be unacceptable, particularly for new composite connectors. Only direct lightning strike effects will be investigated because these are more likely to reveal a problem in the connector materials. In an effort to limit the number of connectors required for tests, this test will be conducted on connector shells that have already been exposed to a 250-hour salt spray test under Phase I. The currents during the test will increase from 5.0 kA to 20.0 kA to provide the EMI engineer with additional data about the ability of the connector to withstand direct lightning strikes.

4.2.4 Shell-to-Shell DC Resistance

Traditionally, shell-to-shell DC resistance has been the standard by which connectors are qualified. Shell-to-shell DC resistance will continue to be important, especially with composite connectors. Of particular concern is the possibility that under temperature conditions commonly encountered in the aircraft composite connectors may de-laminate. In the case of non-composite connectors, different plating layers may separate, leading to an inadequate conduction path through the connector. For this reason, the shell-to-shell DC resistance test is performed after heat treatment. This test is not conducted in Phase I to minimize the test requirements under Phase I.

4.3 Mechanical Specifications

4.3.1 Lubricity

There is a concern that when soft metals are used in connectors, they may meet all the functional requirements but bind up after only a few connection cycles. Since connectors are usually never changed, this was not thought to be a large enough problem to be a disqualifying factor in Phase I. However, it may be a concern for some applications, so a test for lubricity is included in Phase II.

4.3.2 Mating and Unmating Forces

There is a concern that temperature and/or corrosion may cause connectors to bind, particularly for IVD aluminum and zinc alloy connectors. For this reason, mating and unmating force tests will be conducted after the 250-hour salt spray test that follows the Thermal Treatment Test and after immersion in each of the fluids in the Fluid Resistance Test. Because of the complexity of these tests, they have only been included in Phase II.

4.3.3 Physical Dimensions

Composite connector manufacturers have indicated that some of the tight radii of the MIL-C-38999J connector designs make it difficult to maintain an adequate conduction path within the connector. These dimensions are for the most part not critical to the function of the connector. Relaxation of some of these requirements could result in discovery of connectors that meet all the functional requirements and do not contain cadmium and chromium. It is preferred that the dimensions not change. Any variation in the dimensions of connectors that pass the tests in Phase I should be noted in the report in Phase II.

4.4 Environmental Requirements

4.4.1 Corrosion

The salt spray requirement for cadmium-plated connectors from MIL-C-38999J states "unmated connectors shall show no exposure of basis material due to corrosion which will adversely affect performance." This requirement is somewhat subjective. In Phase I, visual inspections, 250-hour salt spray tests, and bond resistance measurements will be made. It is not clear what the normal salt spray environment is for Air Force aircraft, since aircraft stationed near the ocean are exposed to high levels of salt fog while aircraft stationed inland in dry areas are not. Traditional tests are for 500 hours. Testing over a 250-hour period is a reasonable compromise for Phase I. Phase II tests will be conducted for the full 500 hours plus an additional 1500 hours, or until the resistance is no longer acceptable. In addition, Phase II will include tests on aluminum panels coated with a non-chromate conversion coating for an initial 250 hours plus an additional 1500 hours.

4.4.2 Fluid Resistance

Whenever new materials are being considered, the effects of fluids encountered in normal operations need to be considered. Fluid resistance is evaluated during Phase II because not all connectors may be exposed to all the fluids that may be encountered. This is also why the test procedure was modified to include a bond resistance test between each fluid. The test procedure was also modified so that one connector can be used for all the tests to reduce the number of connectors required.

4.4.3 Shock and Vibration

One concern about the current connector system design is that there is inadequate contact pressure between the connector and plate faying surfaces. Testing for shock and vibration may be used to test whether pressure is affected by these common environmental conditions. It is important to note that the vulnerability of the internal electronic contact to shock and vibration is not being tested, but rather the vulnerability of the connector shell mated to the airframe or electronics box. Shock and vibration are not considered mandatory requirements because it is not clear what levels of shock and vibration are needed for any particular application. Also, the vibration testing is time consuming and costly, so this test will not be used as a screening test. Both shock and vibration tests have been included in the Phase II test regime.

4.4.4 Thermal Cycling

Some materials may de-laminate or separate under repeated thermal cycles. Because these temperatures may not be as high as the maximum operating temperatures encountered, this test requirement is different from the thermal treatment test. This test is included in Phase II because it was not considered to be a mandatory requirement; not all applications are subjected to the large temperature fluctuations encountered in this test procedure.

4.4.5 Thermal Treatment

At elevated temperatures some of the plating or composite layers may deteriorate. Traditional cadmium-plated connectors are capable of handling temperatures up to 175°C. It is not clear that all connector applications need to be capable of handling these temperatures so the requirement was not included in Phase I. This issue needs to be addressed if a substitute is to be found that can completely replace cadmium-plated connectors, so the test has been added to the Phase II test program. Lightning strike testing will also cause very high temperatures in the connectors, but these will only be short spikes caused by resistance heating of the connector material itself. The lightning strike test will test those effects.

4.5 *Logistical Factors*

4.5.1 Availability of Technology

Any new materials or technologies developed as part of this effort must be available to be manufactured for Air Force use. However, it is likely that most, if not all, of the manufacturing technologies being investigated will have been developed by private corporations and are therefore not necessarily available from more than one domestic source. In order to avoid development of a connector that is available from only one source, this document includes the requirement that organizations wishing to participate understand that more than one domestic supplier will be required if the candidate connector is to be fielded.

4.5.2 Cost

New connector manufacturing techniques or materials will probably cost more than the current technologies and materials. However, if the costs are exorbitant, new materials will not find their way into the fleet. A query of the DLA database revealed that the price of the cadmium connectors used currently varies by approximately a factor of three depending on the number of contacts and other considerations. A factor of two in the cost of new connectors that do not contain EPA-17 industrial toxic chemicals is deemed acceptable.

4.5.3 Weight

Weight is always a consideration for equipment associated with aircraft. If the weight of new connectors is too high, it is unlikely that the new materials will find their way into the fleet. The 20% greater threshold means that if the new material were included in all connectors in a typical aircraft, the increase in weight would be on the order of 0.1% of the weight of the aircraft. This assumes that there are 1000 cadmium-plated connector pairs per aircraft; each cadmium-plated pair weighs 28 grams (one ounce); and the average aircraft weighs 5,000 kilograms.

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5 Protocols

This section provides the proposed protocols for the following procedures:

- ☐ Attaching connector to plates
- ☐ Bond resistance test
- ☐ EMI leakage attenuation test
- ☐ Fluid resistance test
- ☐ Lightning strike test
- ☐ Long term resistance test
- ☐ Lubricity test
- ☐ Mating and unmating forces test
- ☐ Random vibration test
- ☐ Salt spray test - 250 hours
- ☐ Salt spray test - extended
- ☐ Shell-to-shell resistance test
- ☐ Shock test
- ☐ Sine vibration test
- ☐ Thermal cycling test
- ☐ Thermal treatment test

None of the tests address the internal construction of the connector. Any connectors that show successful results in these tests must still pass additional qualification tests before they can be used in aircraft.

5.1 Attaching Connectors to Plates

Purpose:

This procedure will standardize the way the connector and plate are attached.

Equipment:

1. Plates: Plates shall be 2024-T6 aluminum alloy coated with a MIL-C-81706 Class 3 chemical conversion coat. A standard chromate conversion coat should be used except where noted in the procedures. All chromate conversion coated plates should be coated at the same time using the same coating solution. When the procedures call out a non-chromate chemical conversion coat, it should be a coating such as Alodine 2000 that has passed all of the functional tests for a MIL-C-81706 Class 3 chemical conversion coating.
2. Methyl ethyl ketone.

3. Isopropyl alcohol.
4. Teflon® tape and Teflon® washers (or equivalent): The tape and washers should be able to withstand temperatures up to 175°C and should not react with any of the fluids used in the fluid resistance test described in MIL-SPEC-1344 Method 1016. The washers should be sized for a #4 screw so that there is no conduction path through the head of the screw into the plate.
5. #4/40 screws.
6. Torque wrench: The torque wrench must be capable of measuring torque up to 100 inch-ounces with an accuracy of ± 2 inch-ounce.

Procedure:

1. Clean the plate thoroughly with methyl ethyl ketone and isopropyl alcohol. Let the plate dry before mating with the connector.
2. For the Salt Spray Tests, Fluid Resistance Test, and Long Term DC Resistance Test, make a 1-centimeter scratch that penetrates the chemical conversion coat on the plate in an area that will be completely covered by the connector.
3. Bolt the connector shield to the aluminum plate using four #4/40 screws as specified in MIL-C-38999J. Cover the screw threads with Teflon® (or equivalent) tape and place a Teflon® (or equivalent) washer between the head of the screw and the shell so that there is no conduction path through the screw into the plate.
4. Tighten the screws to a torque of 96 inch-ounces.

5.2 Bond Resistance Test

Purpose:

This procedure will determine the electrical conductivity of connector shells to the aircraft frame (simulated by an aluminum plate).

Equipment:

1. Voltmeter of suitable range certified to an accuracy of ± 2 percent full scale.
2. Ammeter of suitable range certified to an accuracy of 1 percent.
3. Power supply capable of delivering up to 1.0 ± 0.1 ampere.
4. Test probes with spherical end of 0.050-inch minimum radius shall be used to make voltage measurements on the mated plate and connector.
5. An aluminum plate and connector mated according to the procedures in "Attaching Connectors to Plates."

Procedure:

1. Send a test current of 1.0 ± 0.1 ampere at 1.5 volts DC maximum through the shell and plate.
2. Measure the DC resistance between the back surface of the plate and the top surface of the connector shell.
3. Make sure the resistance measurement contacts connect directly to the base metal, penetrating any coatings or plating.
4. Record the resistance value and any observations.

Documentation:

1. Title of test, date, and name of operator.
2. Sample description – include fixture, if applicable.
3. Test equipment used and date of last calibration.
4. Values and observations.

5.3 EMI Leakage Attenuation Test

Purpose:

The purpose of this test is to determine the connector's EMI shielding effectiveness.

Equipment:

1. RFI leakage test fixture, as illustrated in MIL-C-38999J, Figure 24.
2. Procedure:
3. Test connectors in accordance with MIL-C-38999J section 4.7.27, modified to accommodate a shell-to-plate connection.
4. Compare the results with the requirements in MIL-C-38999J for Series III Class W connectors.

Documentation:

1. Title of test, date and name of operator.
2. The nature of the modification to MIL-C-38999J section 4.2.27.
3. Test equipment used and date of last calibration.

5.4 Fluid Resistance Test

Purpose:

This procedure will determine the effects of fluids encountered in normal operations.

Equipment:

1. Connector (a single connector will be used for all tests, unless otherwise specified in the procedure).
2. Plate.
3. The ten fluids, as specified in MIL-STD-1344 Method 1016.
4. Absorbent material.
5. Caps.
6. Deionized water.

Procedure:

1. Inspect the connector before mating it with the plate. Take careful note of the color and surface finish.
2. Mate the connector with a chromate conversion coated plate according to the procedure in "Attaching Connectors to Plates." Make sure the plate is scratched as discussed in that protocol.
3. Measure the bond resistance according to the procedure in "Bond Resistance Test."
4. Fill the open end of the connector with an absorbent. Cap the end to prevent fluid from entering the connector.
5. Immerse the connectors and plates according to the procedures in MIL-STD-1344 Method 1016 (note: mating and unmating forces are addressed in this test method).
6. Remove the cap and absorbent material after each immersion test, before going on to the next fluid. If there is no sign of fluid entering the connector, then replace the absorbent material and recap the connector. If there is any sign of fluid entering the connector, then the insides of the connector should be thoroughly rinsed with deionized water.
7. Rinse the outside of the connector with deionized water.
8. Measure the bond resistance according to the procedure in "Bond Resistance Test."
9. Use a new connector for subsequent immersion tests if the bond resistance increased more than 10% as a result of being immersed in any fluid.
10. Repeat steps 4 through 8 for each fluid.
11. Separate the connector from the plate.
12. Inspect the connector and plate for any discoloration or corrosion. Record any observations.

Documentation:

1. Title of test, date and name of operator.
2. DC resistance measurements.
3. Test equipment use and date of last calibration.
4. Observations.

5.5 Lightning Strike Test

Purpose:

The purpose of this test is to evaluate the effects of a direct lightning strike on the connector shell.

Equipment:

1. Electronic pulse generator capable of generating a double exponential unipolar pulse with a rise time to the peak of $50 \mu\text{s} \pm 20\%$ and a decay time to 50% peak of $500 \mu\text{s} \pm 20\%$ having the general form of the SAE-AE-4L waveform 5B. The generator must be able to supply a peak voltage of between 5 kA to 20 kA.
2. Standard all-metal connector
3. Thirty inches of standard shielded cable.
4. The test sample consists of a candidate connector mated to a plate as described in "Attaching Connectors to Plates." The plug end of the candidate connector is bonded to the cable. The other end of the cable is bonded to the standard all-metal connector plug, which is connected to an all-metal receptacle. The all-metal receptacle is mated to a plate as described in "Attaching Connectors to Plates," however, at this end a high-current by-pass strap is attached. The plate attached to the candidate connector is connected to the pulse generator, and the plate attached to the all-metal connector is grounded.

Procedure:

1. Measure the DC resistance between the two plates using the equipment and technique described in the "Bond Resistance Test" protocol. Record the value.
2. Subject the candidate connector to a pulse with a peak current of 5 kA.
3. Inspect the connector and cable for any damage. Replace the cable or all-metal connector if either is damaged in any way. If the candidate connector is damaged but can still function, do not replace the connector.
4. Measure the DC resistance between the two plates again as in step 1 above.
5. Repeat steps 2 through 4 with 10 kA, 15kA and 20kA voltages.

6. Completely tear down the assembly and examine the connector under 10 times magnification.

Documentation:

1. Title of test, date and name of operator.
2. Sample description – including fixture.
3. Test equipment used and date of last calibration.
4. Traces of the supplied pulse wave form.
5. DC resistance measurements and observations.

5.6 Long Term Resistance Test

Purpose:

The purpose of this test is to investigate the ability for the connector to maintain electrical contact over a period of days. This test should indicate if connector pressure slowly decreases with time or if the connector faying surfaces are particularly susceptible to oxidation.

Equipment:

1. Voltmeter of suitable range certified to an accuracy of ± 2 percent full scale.
2. Ammeter of suitable range certified to an accuracy of 1 percent.
3. Power supply capable of delivering up to 1.0 ± 0.1 ampere.
4. Test probes with spherical end of 0.050-inch minimum radius shall be used to make voltage measurements on the mated plate and connector.
5. An aluminum plate and connector mated according to the procedures in "Attaching Connectors to Plates."
6. A laboratory environment with the temperature in the range of 20-30°C and the relative humidity less than 50 percent.

Procedure:

1. Check the DC resistance according to the "Bond Resistance Test" protocol every day at approximately the same time for a period of 30 days and record the value.
2. Visually inspect the front and back of the connector and plate when checking the resistance and record any visible damage or abnormalities.
3. Do not re-torque the screws under any circumstances.

Documentation:

1. Title of test, identification of test specimen.

2. Test equipment used and date of last calibration.
3. For each day the resistance is checked the date, time, name of operator, DC resistance and any visible damage or abnormalities.

5.7 Lubricity Test

Purpose:

The purpose of this test is to evaluate the possibility of the connector binding up or becoming too loose after repeated uses.

Equipment:

1. Torque measuring device capable of meeting the performance requirements of, and calibrated in both directions in accordance with, MIL-T-26639 (Tester, Torque Wrench, issued March 14, 1969) except the torque-measuring device shall be accurate to + 4% of the indicated readings. Select torque wrenches such that the operating range of the anticipated torque values stays within 20% to 90% of the torque wrench capacity.
2. Mounting fixtures that allow the samples to be mounted in their normal manner.
3. Attachments and accessory type equipment as required to mate the test samples and attach the force or torque gages (i.e., arbor, press, etc.).
4. The connector receptacle should be mounted to a plate as described in "Attaching Connectors to Plates." A mating connector plug should be attached to the mounted receptacle.

Procedure:

1. Follow the procedure in MIL-STD-1344 Method 2013.1. Coupling torque values are given in MIL-C-38999J Table III.
2. Repeat the procedure 15 times.
3. After the 15 repetitions have been conducted, take the coupling apart completely and examine the threaded area from both halves for any thread damage under 10 times magnification.

Documentation:

1. Title of test, date, and name of operator.
2. Sample description – including fixture, if applicable.
3. Test equipment used and date of latest calibration.
4. Values for the mating and unmating torque used for each repetition.
5. Results of the physical examination.

5.8 Mating and Unmating Forces Test

Purpose:

This procedure will determine if temperature effects and/or corrosion cause connectors to bind.

Equipment:

1. Force or torque gauges of applicable range.
2. Mounting fixtures that allow the samples to be mounted in their normal manner.
3. Attachments and accessory type equipment as required to mate the test samples and attach the force or torque gauges.

Procedure:

Test according to MIL-STD-1344 Method 2013.1.

Documentation:

1. Title of test, date and name of operator.
2. Test equipment used and date of last calibration.
3. Values and observations.

5.9 Random Vibration Test

Purpose:

This procedure will determine whether random vibration affects the contact between the connector and plate faying surfaces.

Equipment:

Equipment as specified in MIL-SPEC-1344 Method 2005.

Procedure:

Test according to MIL-C-38999J §4.7.22.2.4 (MIL-SPEC-1344 Method 2005).

Documentation:

1. Title of test, date and name of operator.
2. Test equipment used and date of last calibration.
3. Test results.

5.10 Salt Spray Test - 250 hours

Purpose:

The purpose of this procedure is to characterize the corrosion resistance of the connector when attached to the airframe (simulated by an aluminum plate).

Equipment:

1. The test sample consists of a connector mated to a plate according to the "Attaching Connectors to Plates" protocol. The test sample will be inclined at an angle of no more than 45° from the vertical in such a way as to prevent any pooling of salt spray fluids.
2. Test chamber.

Procedure:

1. This method is identical to MIL-SPEC-1344 Method 1001.1, except the length of the test is 250 hours.
2. Unmated connector ends should be capped to prevent accumulation of salt spray fluids in the connector.
3. No plates from adjacent connectors should be allowed to touch and there should be no electrical conduction path to any metal equipment in the test chamber.

Documentation:

1. Title of test, date and name of operator.
2. Sample description – including fixture, if applicable.
3. Test equipment used and exact constituents used to generate salt spray.
4. Ambient environmental conditions (temperature and humidity).
5. Visual observations before and after the test.

5.11 Salt Spray Test - Extended

Purpose:

The purpose of this procedure is to characterize the corrosion resistance of the connector when attached to the airframe (simulated by an aluminum plate).

Equipment:

See Salt Spray Test – 250 Hours.

Procedure:

1. Mate one connector to a plate with a chromate conversion coat and one connector to a plate with a non-chromic chemical conversion coat according to the "Attaching Connectors to Plates" protocol. Incline the test sample at an angle of no more than 45° from the vertical in such a way as to prevent any pooling of salt spray fluids.
2. Scratch both the plate and the faying connector surface. The scratch should penetrate the conversion coat and plating and expose the structural material of the connector.

3. Do not allow plates from adjacent connectors to touch. There should be no electrical conduction path to any metal equipment in the test chamber.
4. Measure the bond resistance according to the "Bond Resistance Test" protocol.
5. Test connectors according to MIL-SPEC-1344 Method 1001.1, with the following exceptions: Test connectors attached to the chromate conversion-coated plates for 500 hours; test connectors attached to the non-chromate conversion coated plates for 250 hours.
6. Inspect the connector and plate (without separating them).
7. Measure the bond resistance.
8. Return the connectors to the salt spray chamber for an additional 1500 hours. Remove the specimens from the chamber every 100 hours, inspect them, and measure the bond resistance. If the bond resistance exceeds 10 milliohms, the test may be ended for that connector.
9. Once the 1500 hours have been completed or when the bond resistance exceeds 10 milliohms, separate the connector from the plate and inspect both the plate and connector. Make careful note of any corrosion that may have occurred in conjunction with the scratches placed on the plates.

Documentation:

1. Title of test, date and name of operator.
2. Sample description – including fixture, if applicable.
3. Test equipment used and exact constituents used to generate salt spray.
4. Ambient environmental conditions (temperature and humidity).
5. Resistance measurements.
6. Visual observations before and after the test.

5.12 Shell-to-shell Resistance Test

Purpose:

This procedure will determine the bonding resistance with a mated connector.

Equipment:

Equipment as specified in "Bond Resistance Tests."

Procedure:

Use MIL-STD-1344 Method 3007.

Documentation:

1. Title of test, date and name of operator.
2. Test equipment used and date of last calibration.
3. Resistance measurements.

5.13 Shock Test

Purpose:

This procedure will determine if shock affects the contact between the connector and plate faying surfaces.

Equipment:

Equipment per MIL-STD-1344 Method.

Procedure:

Test connectors according to the procedures outlined in MIL-C-38999J Section 4.7.23.1 for "Standard Shock."

Documentation:

1. Title of test, date and name of operator.
2. Test equipment used and date of last calibration.
3. Test parameters (i.e., magnitude and duration of pulse).
4. Test results.

5.14 Sine Vibration Test

Purpose:

This procedure will determine if sine vibration affects the contact between the connector and plate faying surfaces.

Equipment:

1. Vibration generator.
2. Equipment specified in "Bond Resistance Test."

Procedure:

1. Test connectors according to the procedures outlined in MIL-C-38999J Section 4.7.22.2.1 for qualification testing; only sections applicable to Series III apply.
2. Measure the bond resistance between each test according to the procedure given in "Bond Resistance Test."

Documentation:

1. Title of test, date and name of operator.

2. Test equipment used and date of last calibration.
3. Vibration parameters (i.e., vibration envelope, temperature, and duration).
4. Bond resistance.

5.15 Thermal Cycling Test

Purpose:

This procedure will determine whether temperature fluctuation will affect the bond.

Equipment:

1. Equipment as specified in "Bond Resistance Test."
2. Thermal cycling equipment.

Procedure:

1. Inspect the connector, making careful note of the dimensions, color and surface finish.
2. Mate the connector to a chromic conversion coated plate according to the procedure in "Attaching Connectors to Plates." Do not scratch the plate surface for this test.
3. Measure the bond resistance according to the procedure in "Bond Resistance Test."
4. Subject the connector and plate to thermal cycling as described in MIL-SPEC-1344 Method 1003.1 test condition A.
5. Measure the bond resistance again.
6. Separate the connector from the plate and re-inspect it. Make careful note of any changes that occurred after the initial inspection.

Documentation:

1. Title of test, date and name of operator.
2. Test equipment used and date of last calibration.
3. Thermal cycle temperatures and times.
4. Bond resistance after thermal cycle.
5. Observations.

5.16 Thermal Treatment Test

Purpose:

The purpose of this test is to determine if there are any materials that cannot withstand moderate temperatures that could be encountered in nominal aircraft environments.

Equipment:

1. Dry oven capable of maintaining a temperature of $175^{\circ} \pm 10^{\circ}\text{C}$.
2. Connector and plate mated together according to the "Attaching Connectors to Plates" protocol.

Procedure:

1. Visually inspect the connector and plate and record any observations, including dimensions, color, and surface finish.
2. Place the mated connector and plate in the oven for a period of 6 hours at a temperature of $175 \pm 10 / -0^{\circ}\text{C}$.
3. Remove the mated connector from the oven after 6 hours. Let it cool to room temperature for a minimum of 1 hour.
4. Visually inspect the mated connector and record any observations.

Documentation:

1. Title of test, date and name of operator.
2. Test equipment used and date of last calibration.
3. Results of visual inspections before and after heat treatment.
4. Temperature of heat treatment.